AUTOMATIC TUNING OF MODEL PREDICTIVE CONTROLLERS BASED ON MULTIOBJECTIVE OPTIMIZATION

M. FRANCISCO and P. VEGA

Dpto. de Informática y Automática, ETSII de Béjar. Universidad de Salamanca (Spain)
mfs@usal.es; pvega@usal.es

Abstract—In this work a general procedure for tuning multivariable model predictive controllers (MPC) with constraints is presented. Control system parameters are obtained by solving a multiobjective optimization problem. The set of objectives includes controllability aspects, in terms of the $H_\infty$ norms of some closed loop transfer functions of the system, and others related to the range of manipulated and controlled variables, expressed using the $l_1$ norm. Moreover, the use of multiple linearized models for tuning, allows for the specification of robust performance criteria through a set of constraints. The mathematical optimization for tuning all controller parameters is tackled in two iterative steps. First, integer parameters are obtained using a specific random search, and secondly a sequential programming based method is used to tune the real parameters. As a validation example, the tuning of the control system for the activated sludge process of a wastewater treatment plant has been selected.

Keywords—Model predictive control, activated sludge process, mixed sensitivity problem, robust control theory, $l_1$ norm.

I. INTRODUCTION

Model Based Predictive Control (MPC or MBPC) has become the leading form of advanced multivariable control in the process industries. The popularity of MPC is due to the successful results, the natural way of incorporating constraints, and its simplicity for operators. Excellent reviews of MPC and comparisons of commercial MPC are given in Maciejowski (2002) and Qin and Badgwell (2003).

MPC controllers have been tuned traditionally by a trial and error procedure, determining prediction and control horizons, input and output weights in the objective function, and constraints. The tuning task can be particularly difficult if the system is multivariable, since the whole set represents a formidable array of possible tuning combinations and also because many of these parameters have overlapping effects on the closed-loop performance and robustness. In these cases the advantages of using automatic MPC tuning methods is clear.

In the literature there are many works dealing with automatic tuning of MPC, but due to their complexity and the difficulty to perform analytical studies, the development of a general method is still a challenge. Some researchers have proposed tuning methods for specific types of MPC, or leaving apart some particular aspects of the problem, for instance not considering the horizons (Li and Du, 2002). In other works, tuning methods have been developed considering simplifications in some way. For instance, Sridhar and Cooper (1997) focused on a single input, single output case with first order plus dead time models and Al-Ghazzawi et al. (2001) developed a tuning method based on a linear approximation between the closed loop predicted output and the tuning controller parameters. Some other papers that also deal with the tuning problem of MPC are Abu-Ayyad and Dubai (2006), Liu and Wang (2000) and Van der Lee et al. (2008).

Many researches pay also attention to the tuning of MPC by solving different optimization problems. Ali and Zafiriou (1993) proposed an off-line procedure for the non linear MPC tuning specifying time performance criteria, and incorporating a random grid search for obtaining the horizons. Li and Du (2002) developed also a simulation-optimization method based on fuzzy decision criteria for tuning only the weighting factors of the control variables. In Francisco et al. (2005) and Francisco and Vega (2006) the authors describe a new methodology for the on-line automatic tuning of the whole set of parameters of linear MPC, carried out by minimizing dynamical indexes as performance measures. An important drawback of these works is the required dynamical simulations within the optimization algorithm, making the procedure extremely slow.

Frequency domain methods for tuning linear optimal controllers have been studied since the beginning of 1980’s (Doyle et al., 1992), and they are a good alternative to speed up MPC automatic tuning procedures avoiding dynamical simulations. Based on that, the authors propose in Vega et al. (2007) a tuning procedure by solving a mixed sensitivity problem with constraints using a nominal model of the process. However, due to the use of a single linearized model, some problems of stability and robustness were detected in the presence of nonlinearities and load disturbances acting on the plant. For these reasons, the objective of this work is to propose a general methodology in which predictive controllers are tuned systematically using multiple models and robust theory fundamentals to guarantee robust performance (Morari and Zafiriou, 1989; Sideris and Rotstein, 1993; Tadeo et al., 1998).

Another reason to use frequency domain techniques for tuning is that they provide the way to analyse some properties of the feedback system that time domain techniques do not. For example, disturbance rejection within a range of frequencies, not only considering a